IDENTIFYING RED-BANDED THRIPS (*Selenothrips rubrocinctus* Giard) RESISTANCE IN GUAVA (*Psidium guajava* L.)

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INTRODUCTION

Guava (*Psidium guajava* L.) was first mentioned as a host for the red-banded thrips (*Selenothrips rubrocinctus* Giard) in Hawaii in 1910 (Bagnall, 1910). Today, it is recognized as a major pest of guava (Mitchell 1973). Heavy damage to commercial and wild guavas on Oahu, Hawaii was reported in 1967, 1968 and 1969 (Cooperative Economic Insect Reporter 1967, 1968, 1969). Light infestations of the red-banded thrips cause silvering of guava leaves (Purseglove 1968, Mitchell 1973), while severe infestations can cause defoliation (Smith 1953). Infested guava fruits become scarified (Mitchell 1973) and eventually turn brown (Ruehle 1948), making it difficult to know when the fruit is ready for harvest. The attack on very young fruits may cause fruit drop and a subsequent loss in productivity.

Guava has been grown and processed commercially in Hawaii for many years. It is most often processed and stored frozen as puree. Later on it is reprocessed to make nectars and other beverages, as well as james, jellies, bakery and dairy products (Brekke 1973). Guava juice has 2-5 times more vitamin C content than orange juice (Hamilton and Wenkam 1967). Traditionally, most guavas have been picked from wild stands. Recently, there has been interest in developing the guava as an industry in Hawaii. This would require cultivated orchards in which plant growth, harvesting and fruit quality can be controlled (Bullock 1973, Gerakas and Lee 1974).

Since red-banded thrips can be very destructive on guavas and since pesticides are expensive and the object of intense regulation by the Environmental Protection Agency, this study was initiated to find out if variation in resistance exists in guava and, if it does, to develop suitable methods for identifying useful levels of resistance.

REVIEW OF LITERATURE

Guava

Origin and Distribution

The guava is native to Tropical America where it was first discovered by early Spanish and Portuguese explorers. These explorers introduced the fruit to the Philippines, India and elsewhere and it has become naturalized in many tropical countries. The guava was brought to Hawaii by Don Marin around 1800 (Hamilton and Seagrave-Smith 1954). It is often considered to be a noxious weed especially in pastures.

Botany of the Crop

The guava belongs to the Myrtaceae or Myrtle family (Neal 1965). It is a small, low branching tree or shrub which ranges from 3-10 meters in height (Allen 1967). Suckers often grow from the roots. The smooth green or reddish brown bark peels off in thin layers, leaving a mottled pattern on the trunk (Neal 1965). Young twigs are square in cross-section, pubescent and green in color (Ruehle 1948, Chandler 1964).

The leaves are opposite with short petioles 3-10 mm long. The blade is oblong to oval from 5-15 cm long, smooth on top and hairy beneath. It has a prominent pinnate venation, indented above and raised below (Neal 1965, Purseglove 1968, Chandler 1964).

The flowers are axillary with a persistent calyx. They are borne singly or in 2-3 flowered cymes (Purseglove 1968).

The inferior fruit is a many seeded berry with the persistent calyx often attached at fruit maturity. Fruit shape varies from round and oval to pyriform. The immature fruit is light green, becoming bright yellow at maturity. The exocarp is very thin. The mesocarp color varies from white to pink, salmon or even sulfur yellow, depending on the cultivar. The seeds are usually imbedded in the pulp (Neal 1965, Chandler 1964, Allen 1967, Purseglove 1968).

Other related species with edible fruits include the strawberry guava (*P. cattleianum* Sabine), its botanical form *lucidum* Degener, *P. guineense* Sub and *P. friedrichsthalianum* (Berg.) Nied.

Red-Banded Thrips

Classification

The red-banded thrips belongs to the family Thripidae which is in the sub-order Terebrantia of the order Thysanoptera (Lewis 1973).

The Red-banded thrips was originally identified and named by Giard in Paris in 1901 from specimens from the West Indies and then in 1908 Franklin reclassified the genus on the basis of structure and called it *Heliothrips rubrocincta* (Urich 1911). Karny then placed this insect in a new sub-genus that he called *Selenothrips rubrocinctus* in 1911 (Russell 1912). Inasmuch as it was first identified on cacao, the insect was generally called cacao thrips. In Florida where cacao is not grown, this thrips was observed attacking mango and avocado. It was given the name red-banded thrips because of the red band across the first two abdominal segments (Russell 1912).

Origin and Distribution

It is generally agreed that the red-banded thrips is native to tropical America (Urich 1911, Russell 1912, Reyne 1921, Callan 1943a). However, in 1909 Maxwell-Lefroy reported that the red-banded thrips was introduced to the West Indies from Ceylon (Russell 1912). This thrips is widespread throughout cacao growing countries in the African and American tropics (Callan 1943a, Russell 1912) as well as in the tropical islands in the Atlantic and the Pacific (Russell 1912). It was also been reported in Mexico (Johansen 1974), Florida (Russell 1912) and in India (Ananthakrishnan and Muraleedharan 1974). It will probably not move any farther north than Florida since it is a tropical insect (Russell 1912).

Hosts

Cacao (*Theobroma cacao* L.) and cashew (*Anacardium occidentale* L.) are the two most important commercial host plants of the red-banded thrips (Fennah 1963). Many other common tropical plant species have been reported to be hosts. These include the following plants: guava (*P. guajava*), *polycarpum*, mango (*Mangifera indica* L.), tropical almond (*Terminalia catappa* L.), avocado (*Persea americana* Mill.), rose apple (*Eugenia jambos* L.) and macadamia (*Macadamia integrifolia* Maiden and Betche (Reyne 1921, Ananthakrishnan and Muraleedharan 1974, Russell 1912, Cooperative Economic Insect Reporter 1974). Cashew was preferred over rose apple, mango and guava (Ananthakrishnan and Muraleedharan 1974). In Surinam the red-banded thrips preferred fully expanded new leaves of plants in the following order: lipstick plant (*Bixa orellana* L.), *Jambosa vulg*. (sic), mango, tropical almond and cacao (Reyne 1921).

Biology of the Red-Banded Thrips

Females are usually more abundant than males in most thrips species. No males of the red-banded thrips were observed in the West Indies by Russell (1912), but a few were observed in Trinidad by Urich (1911). In Surinam 16 males were recorded in a population of 1107 red-banded thrips (Reyne 1921). Likewise, the male to female sex ratio of the onion thrips (Thrips tabaci Lindeman) varied from 1:1 in the eastern Mediterranean region to 1:1000 in Hawaii and 0:3000 in the Sudan (Lewis 1973).

Red-banded thrips eggs are usually inserted singly in the lower epidermis of the leaf or in a protected area of the epidermis of the fruit. It takes approximately 12 days for the first instar to emerge at temperatures between 20 and 30°C (Bailey 1935). The duration of the first and second larval instars varies from 6 days to as long as 16 days, depending on temperature (Reyne 1921, Bailey 1935, Russell 1912). The third or prepupal instar lasts about 1-4 days and the fourth or pupal instar, 1-7 days, again depending on temperature (Russell 1912, Reyne 1921).

The shortest total life cycle observed was 16-18 days in Trinidad. In a Washington D.C. greenhouse at 21.1°C the total life cycle ranged from 28-43 days (Russell 1912).

The first two larval or nymphal instars are the feeding stages. The last two instars, the prepupal and pupal instars are non-feeding stages (Lewis 1973).

Thrips populations are usually lowest during the rainy season due to unfavorable conditions for reproduction (Urich 1911, Reyne 1921). Populations on cashew rise drastically during the dry season in Trinidad. However, on cacao the population has been observed sometimes to increase even during the wet season in Trinidad (Fennah 1963).

Morphology of Thrips Stages

The egg of the red-banded thrips is thin, transparent and kidney shaped, 0.26 mm long and 0.10 mm wide (Urich 1911).

A newly hatched larva is translucent, spindle-shaped and about 0.25 mm in length. The head is cubical and pale yellow with red eyes. The antennae are 7 or 8-segmented. The abdomen is 10-segmented. The first and second abdominal segments are banded by a bright red pigment. There are 4-6 long setae at the tip of the abdomen (Russell 1912). Normally, this first instar larva molts around the fifth day (Russell 1912, Reyne 1921).

The second stage larva has a longer, more cylindrical body than the first stage, measuring approximately 1.01 mm in length. The color of the body is translucent white to pale orange with a very prominent red band on the first 3 abdominal segments. The body is also covered with many bristly black setae. The last abdominal segment bears 4 long black hairs. Antennae are 7-segmented extending foreward from the head. The eyes are red and the legs are hyaline (Russell 1912).

The fusiform shape of the prepupa closely resembles the shape of the adult thrips. It is 1.09 mm long and 0.26 mm wide. Three pairs of setae are present on the head; 2 behind the head and 1 between the eyes. The 7-segmented antennae are translucent white with an orange-tipped first segment and extend foreward from the head. The forewing and hindwing pads are distinct, translucent white, and extend to the second and third abdominal segments, respectively. A band of bright red pigment covers half of the first and all of the second and third abdominal segments. Numerous rows of setae cover the body, head and legs (Russell 1912). The prepupa has no mouthspines for feeding (Reyne 1921).

The pupa also has the same general shape as the adult. It is 1.02

mm long and 0.26 mm wide. The coloration is approximately the same as that of the prepupa. The red eyes are larger than in the prepupal stage and there are 3 ocelli in a triangle between the eyes. The antennae in this stage conspicuously project backwards, and lie on the head (Russell 1912).

On emerging, the adult female is translucent, but after the first day, the body turns black. No red band is visible. Its body length varies between 1.10 and 1.40 mm long. The male has a much smaller body with a tapering, slender abdomen. Four feather-like wings, that do not extend beyond the abdomen, are present. The antennae are once again projecting foreward (Urich 1911, Russell 1912, Reyne 1921).

Habits of the Adult

Adults generally feed on the underside of leaves but may occasionally be found on the upper leaf surface. They are often found feeding in colonies with larvae and pupae near leaf veins. When disturbed, they will jump or crawl quickly away. Jumping is accomplished by a sudden beating of the wings (Reyne 1921). On cacao the female chooses tender young leaves on which to deposit her eggs. She inserts them one at a time into holes made by the ovipositor in the epidermal layer. The egg in each hole is then covered by a drop of fecal matter which serves to conceal and protect the egg (Russell 1912, Urich 1911).

Habits of the Larvae and Pupae

The larvae on cacao are generally found feeding on the underside of the leaves. They are often seen feeding with adults and near pupae. If the colony is not disturbed and the food supply is good, they will remain on one side of the leaf throughout their entire life cycle. One striking characteristic of the larvae is the ball of liquid excrement which is always carried at the tip of its uplifted abdomen supported by 6 long hairs. When this fecal drop becomes too heavy to support, it is voided on the leaf where it dries and turns brown. Larvae prefer the shade to the sun. If exposed to bright light or heat they move rapidly in search of cooler shady areas (Reyne 1921, Russell 1912).

Description of Injury and Mode of Feeding

A description of the structure of the mouthparts of thrips is necessary for understanding their mode of action. Thrips mouthparts, located under the first segment of the thorax, form a wide conical proboscis known as the mouthcone. This cone is bent downwards and backwards at a 45° angle to the body. The tip of the cone is usually blunt but may be sharply pointed. All thrips mouthcones are asymmetrical. The face of the cone consists of the clypeus and the labrum which are slightly separated by a membrane. Both sides of the cone consist of the triangular shaped part of the maxilla which bears a tri-segmented palp. The back of the cone is formed by the labium bearing two bi-segmented palps at its tip. The labium serves as a flexible flap since it extends past the labrum and the maxillae. The tips of the labium are hook-like and are used to grasp the surface of the feeding site (Wardle and Simpson 1927, Lewis 1973).

Housed inside the cone are the piercing organs: Two thin maxillary stylets, the more heavily sclerotized left mandibular stylet, and, in some species, a median stylet or hypopharynx may be present (Wardle and Simpson 1927, Lewis 1973). Mouthparts of larvae are similar to those of adults.

The Red-banded thrips feeds by piercing the epidermis and then rasping or scraping away the leaf tissue within (Russell 1912). A study of the feeding habits of the onion thrips shows that they do not pierce, puncture, scrape or rasp the epidermis but they gash the outer cell wall with the mandible which protrudes and retracts with each upward and downward rocking motion of the head. Ordinarily, the mandible only protrudes far enough to gash the epidermal cell wall. The inner cell walls are broken in a similar fashion by the longer maxillary stylets. The pick axe-like movement of the head stops when the cell walls are all broken and then the thrips sucks up the plant juices (Wardle and Simpson 1927, Mound 1971, Lewis 1973).

Thrips can be found feeding on all parts of host plants including leaves, stems, fruits, buds and flowers. They usually prefer the lower surfaces of leaves which generally have a thinner epidermis than the upper surface (Wardle and Simpson 1927, Callan 1943a, Ananthakrishnan 1971, Lewis 1973). The upper leaf surface may be the preferred feeding site on some plants with a hairy leaf surface (Jones et al 1934, Ananthakrishnan 1971). Red-banded thrips generally feed on the lower surface of fully expanded leaves on cacao and cashew. On guava they have been observed feeding on both leaves and fruits (Cooperative Economic Insect Reporter 1969).

Injury caused by thrips may appear differently on different plant hosts. In general the first signs of thrips damage are small shiny silver areas on the surface of the infested area. The "silvering" is due to empty cell cavities filled with air, magnified by a lens effect of the intact outer epidermal cell wall. The tissues below the epidermal layer may dry up and turn brown. If the thrips infestation is heavy these brown spots coalesce. A whole leaf may dry up, turn brown and fall off prematurely (Ananthakrishnan 1971, Lewis 1973).

Cacao, mango and cashew are all defoliated by severe attacks of the Red-banded thrips. It is the continual defoliation which does the most damage. In Surinam cacao pods turn brown when attacked so the fruits must be scraped with a sharp object to determine ripeness. Heavy thrips infestations can cause some cacao trees to die. Others survive but may not bear fruits (Reyne 1921). Wild guavas on San Thome were defoliated and killed by a heavy thrips infestation (Urich 1928).

Thrips may also damage leaves and fruits in the process of oviposition. Damage may also occur from the deposition of fecal matter on the fruits and leaves, leaving unsightly, discolored spots caused by the dried feces and an associated fungus (Lewis 1973, Ananthakrishnan 1971). During the larval stage 6-10 relatively large fecal drops are produced. Adults deposit about 10 fecal drops per day, but these are smaller than those produced by the larvae (Reyne 1921).

Insect Resistance

Definition

Resistance stems from the interrelationship between plant and insect. The classic definition of insect resistance is given by Painter (1968):

> Resistance of plants to insect attack may be defined as the relative amount of heritable qualities possessed by a plant which influence the ultimate degree of damage done by the insect. In practical agriculture it represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population.

Levels of resistance have been classified as follows:

Immunity is the absence of any damage or infestation.

High resistance is the presence of a very low level of damage or infestation.

Low resistance is the presence of less damage or infestation than average.

Susceptibility is the presence of average or above average damage or infestation.

High susceptibility is the presence of much higher than average damage or infestation.

Three other causes of the lack of damage or infestation may occur. These are host evasion, induced resistance and escape. They are all categorized as pseudoresistance (Painter 1968). Host evasion occurs when a plant passes through its susceptible stage while the insect is either not present or present only in low numbers. Induced resistance may be a temporary increase in resistance due to environmental changes around the plant. Escape is the lack of infestation of a susceptible plant due to the nature of the insect population activity, distribution, or chance (Painter 1968).

Mechanisms of Resistance

It is desirable to know the mechanism of resistance in order to develop possible screening methods and adopt an appropriate breeding technique. Three mechanisms have been identified which may be involved individually or in combination to impart resistance to a plant (Painter 1968). "Preference or non-preference is used to denote the group of plant characters and insect responses that lead to or away from the use of a particular plant or variety for oviposition, food or shelter or combinations of the three (Painter 1968)." Antibiosis is the "tendency to prevent, injure or destroy (insect) life (Painter 1968)." Insects feeding on a plant with such a mechanism may be affected by reduced fertility, reduction in size, longer life cycle and higher mortality in the first instar. Tolerance is the ability of the plant to recover from insect damage in the presence of insect populations comparable to those supported by susceptible plants (Painter 1968).

Preference is the mechanism involved in imparting resistance in the following cases. Infested leaves of susceptible guava, mango, rose apple and cashew plants were found to have high concentrations of free amino acids while plants of the same species with non-infested leaves had fewer free amino acids in lower concentrations. Cashew, which had more free amino acids in higher concentrations than guava, rose apple and mango, was the most susceptible plant host tested. There was no difference in susceptibility among the latter three species (Ananthakrishnan and Muraleedharan 1974). Part of the resistance in the onion variety White Persian is due to its morphology and growth habit. It has rounded leaves which touch each other in a limited plane whereas other, more susceptible, varieties have flat leaves with a greater surface area touching each other, thus providing more protection from the surrounding environment. The White Persian also has wider angles formed by the leaf blade with the sheath which again provides less protection than the more susceptible varieties (Jones el al 1934).

The following are examples of antibiosis mechanisms. The resistance to the red-banded thrips in cacao is reported to be most likely due to the thickness of the leaf which resists puncturing by the insect (Callan 1943a). Onions which are resistant to onion thrips have a thicker epidermis than the susceptible varieties (Jones et al 1934).

Cotton resistance to the onion thrips is partially attributed to the thickness of the epidermis of the leaf. However, it was found that a few resistant varieties had very thin epidermal layers (Abdel-Gawaad et al 1973). Gossypol, a naturally occurring insecticidal substance found in all the glanded varieties of cotton (Bottger et al 1964) is being studied as a possible cause of thrips resistance in cotton (Gawaad and Soliman 1972).

Tests for Thrips Resistance

A three step program was set up to identify red-banded thrips resistance in cacao in Trinidad. The first step was the selection of trees which had few or no thrips in the field, while surrounding trees were heavily infested. In the second step the apparently resistant trees selected in the field were subjected to a series of laboratory tests. Food preference tests on leaf disks with first instar larvae in a large petri dish showed significant differences. Obligatory food tests with first instar larvae on whole leaves inside a large jar for 10 days showed that 50% of the larvae on the resistant type were dead and the live ones were small and unhealthy, while only a few larvae on the control leaves were dead and the live ones appeared healthy. Obligatory food tests on cuttings in the greenhouse showed much less evidence of feeding on the resistant type than on the control. When the resistant type was planted in a heavily infested area it proved to have good resistance (Callan 1943a).

Thrips resistance in peanuts (Arachis hypogaea L.) was measured in the field by counting thrips on foliar buds and by rating damage to leaves. Color photographs showing each level of damage were used for reference (Young et al 1972).

Antibiosis or obligatory food tests and preference tests were carried out in the laboratory to determine peanut resistance. In the antibiosis tests the coefficient of variation was 58%, and there were few significant differences. The preference tests, however, showed significant differences (Kinzer et al 1972).

Nakasone (unpublished data) rated damage on guava trees in the field. Differences in levels of infestation were constant over a period of 1 year.

MATERIALS AND METHODS

Host Plants

All guava plants utilized for this study are located at the University of Hawaii, Waimanalo Experimental Farm in three fields designated J-1, J-2, and Q-2. Planted in J-1 are 4 replications of 7-year old trees of cultivar Beaumont (B-30) and 10 clones selected for high yield and fruit quality. Two trees of each clone were used in this study. 'Beaumont' is a local seedling selection of unknown parents and clones 132, 143, 148, 156, 157, 159, 168, 176 and 180 are all seedling selections of 'Patillo.' Clone 196 is a seedling selection of the cultivar Pink Acid. Clones 156, 148 and 180 had been rated resistant for summers. The others were not rated (Nakasone, unpublished data). Planted in J-2 are a total of 780 trees which are 3-year old open pollinated seedlings from clones 132, 143, 148, 156, 157, 159, 168, 176, 180, 188 ('Patillo' seedling) and 196. A total of 132 of these seedlings were selected for this study. They consisted of 12 seedlings from each of 11 clonal parents. Each set of 12 progeny included four which had appeared susceptible and 8 which had appeared resistant in a previous rating (Nakasone, unpublished data). Fruits from one tree of the newly named cultivar Ka hua kula (097) a selected seedling of 'Beaumont' were used in the laboratory.

The 3-year old trees in field J-2 were spaced 6 feet within rows and 12-15 feet between rows. The trees had been allowed to grow without pruning so that branches of adjacent trees overlapped and many low growing branched touched the ground. Thus, in the row there was a continuous mass of foliage not quite as dense as a hedge row. These trees were all fertilized in May 1975 with 3 pounds each of a 15-15-15 mix except for the individual trees 156-4 and 156-9 which were fertilized with 10 pounds of the same mix and tip pruned in an attempt to force them to flower and fruit at the same time so they could be used in an antibiosis test.

Trees in field J-1 were spaced 18 feet within rows and 25 feet between rows. These trees had been pruned to a single trunk type of growth and the lower branches touching the ground and those interfering with mechanized operations had been removed. Clonal trees used in laboratory experiments were each given 10 pounds of a complete 15-15-15 fertilizer mix in February 1976.

Pesticides were purposely not sprayed in fields J-1 and J-2 to allow natural insect populations to build up.

Several alternate hosts for the red-banded thrips are planted in fields near J-1 and J-2. Macadamia and other guavas are planted in fields to the north. Mangoes border J-1 and J-2 on the south. More mangoes and two cashew trees are in an arboretum to the west.

Thrips for experiments were collected from a tropical almond tree in the arboretum at the Waimanalo Experimental Farm, or from *Psidium araca* planted in 5 gallon pots on the Manoa Campus of the University of Hawaii.

Field Sampling

Thrips population counts in the field were used to measure the differences in levels of infestation between trees and differences in seasonal abundance and spatial distribution of thrips in the field.

Monthly thrips counts were made on 132 open pollinated guava seedlings in field J-2. Thrips were counted on a sample of twenty leaves per tree that were fully expanded and hardened, on the present year's growth generally one or two nodes into the brown portion of the twig and were from protected areas of the tree (close to but not touching the ground). The samples were placed in a plastic bag and stored in a refrigerator in the laboratory until they could be counted. Thrips counts were made with the aid of a hand lens or a very low powered disecting microscope. All samples were taken on the last two days of each month. Since October 1975 was the month with the highest thrips population and a cursory examination of the data for the remaining 11 months showed a distribution similar to that in October, the October data was analyzed with a heirarchical design to indicate trends in thrips infestation for the year. The sample size of 20 leaves was found to be more than sufficient since optimum sample was calculated to be 6 leaves with the formula given by (Lewis, 1973) $n = \frac{100s^2}{m^2}$ where n = sample size, m = the sample average and s = the standard deviation.

Correlations were made between monthly thrips populations and average minimum monthly temperature, average maximum monthly temperatures, and total monthly rainfall. A multiple correlation was made among monthly thrips populations on the 6 most susceptible trees average minimum monthly temperature and total monthly rainfall using the formula $r_{12.3} = \frac{r_{12} - r_{13}\, r_{23}}{(1 - r_{13}^{2})(1 - r_{23}^{2})}$ from Snedecor and Cochran (1967) r_1 = r_2 = total thrips, and r_3 = minimum temperature. It was thought that the trees with the heaviest infestation would be the most likely to show any effects of temperature and/or rainfall.

Thrips counts were also made on the clones in field J-1. Two trees of each of the 11 clones were sampled for 8 months in the same manner as the seedlings in Field J-2. These data were analyzed using a randomized complete block design.

Antibiosis Tests on Two Sister Trees in the Field

Obligatory food tests on leaves and fruits on 2 seedlings of clone 156 at 2 different times, August 11 - September 15 and October 23 - November 21, 1975 were carried out to test thrips survival on an apparently susceptible seedling and an apparently resistant seedling and to measure the amount of damage done by a known number of thrips. In the August-September period only leaves were tested. In the October-November period both leaves and fruits were tested.

Thrips in the pupal stage were transferred from leaves of a tropical almond tree with a 000 camel's hair brush into cages on the leaves or fruits of the guava trees. The cages on the leaves were small celluloid cages around a single leaf similar to that illustrated by Peterson (1947) in Plate #31 (Fig. 1). The dimensions of the .1 mm thick acetate sheet for the leaf cage are 11.5 x 25.5 cm. The organdy sleeve is also 11.5 x 25.5 cm and the end piece of organdy is 11 cm in diameter. The acetate sheet is first taped together with a thin strip of double-stick tape then glued forming a cylinder. The 11.5 x 25.5 organdy is fastened to the end of the cylinder with tape and glue forming a sleeve and then the 11 cm organdy piece is attached to the open end forming a cage 8 cm in diameter and 21 cm in length. After 30 days the leaves or fruits were removed from the trees (still in the cages) and taken to the laboratory where counts were made of the number

FIGURE 1. ANTIBIOSIS CAGE

of thrips alive per leaf or fruit and the percentage of the leaf surface which had turned silver (Fig. 2) or the percentage of the fruit surface which had been sacrified and covered with fecal matter (Fig. 3) was estimated. The completed fruit cage is shorter than the leaf cage. It is 9 cm in diameter and 16 cm long. The cylinder made from a rectangular piece of acetate sheet 8 x 27.5 cm and the sleeve is made with a piece of organdy 11 x 26.5 cm. The end is covered with organdy 12 cm in diameter.

Five initial numbers of thrips were transferred into the cages: 0, 1, 5, 10, and 20. Four replications were used for each antibiosis test on either leaves or fruits on each plant at each time. One cage was found missing in each of five separate tests, thus it was necessary to calculate a value for the missing data with the formula given by Cochran and Cox (1957). Comparisons were made between individual trees, between leaves and fruits on the same tree, and between leaves in the two periods using only the 5, 10, and 20 initial cage populations. Treatment means were compared using LSD or Cochran's t' method of analysis of independent samples when the variances are different (Snedecor and Cochran, 1967). Correlations were made between percent damage and both the initial and final number of thrips per leaf or fruit.

Life Cycle Study

A life cycle study of the red-banded thrips on guava leaves was initiated to establish the normal length for the cycle on guava. Forty-four, 1-day old larvae were placed on 44, 1.5 cm square sections of fully hardened 'Beaumont' guava leaves which were floated on water in 44, 60 x 15 mm petri dishes, one to a dish in the laboratory at room

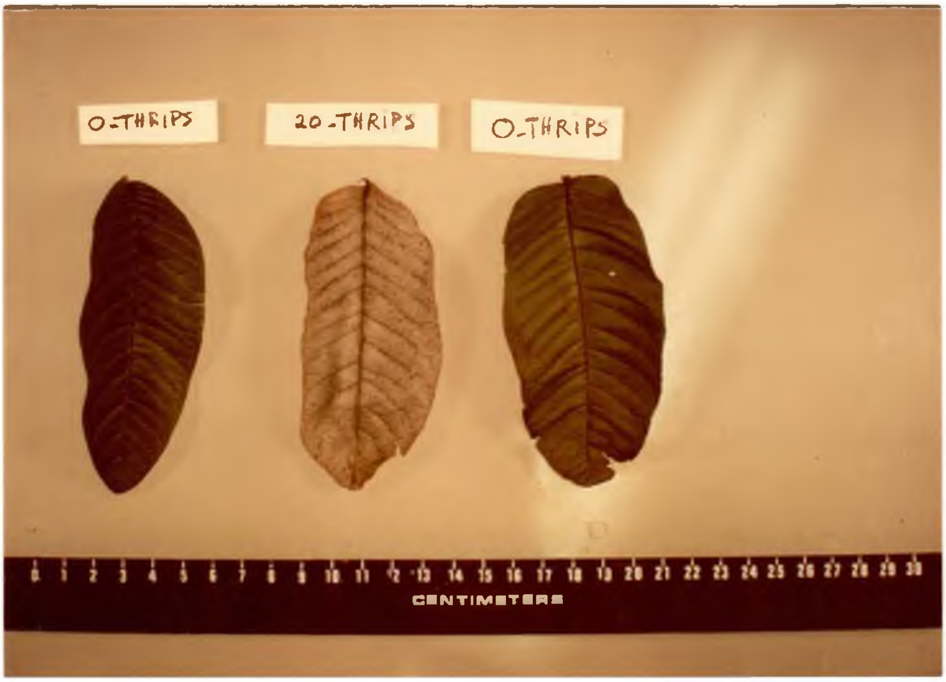

FIGURE 2. LEAF DAMAGE RATING
Middle Leaf = 100% Silvering
Outer Leaves = 0% Silvering

FIGURE 3. FRUIT DAMAGE RATING
3 Fruits on Left = 100% Russeting
3 Fruits on Right = 0% Russeting

temperature ($22.2^{o}C$) (Callan, 1947) (Fig. 4). Daily observations were made and records kept on the number of days per instar and the general physical condition and habits of the thrips.

Preliminary Preference Tests on Leaves

The following non-replicated or low replicated observational tests were set up to refine laboratory methods and cages:

1. Blotter Paper vs. Agar Medium--In this test whole leaves, half leaves, and leaf disks of guava (Fig. 5) were placed in 150 x 15 mm petri dishes on either moistened blotter paper or embedded on the surface of a 2% agar medium. Leaves on blotter paper began drying and curling within a few hours while those on agar remained fresh for up to 2 weeks. The 2% agar also supported the leaves, limited the thrips to the lower leaf surface, and provided a surface which connected the leaves so the thrips could easily move from one to another. On the basis of these observations the agar method was adopted.

2. Cashew vs. Guava--Since cashew has been reported to be a preferred host over guava (Ananthakrishnan and Muraleedharan 1974), a test was set up to see if this preference test could detect this. Eighteen leaf disks of each cashew and guava were cut with a #15 cork borer (2.1 cm in diameter) from fully expanded and hardened leaves of cashew and 'Beaumont' guava. The disks were embedded alternately on the surface of 2% agar in a petri dish. Approximately 80 adult thrips were released in the dish which was covered immediately. Two replications were made. After 2 days counts were made of the number of thrips per disk. Chi-square was used to compare the number of thrips on cashew versus guava.

3. Guava Clones 143 and 168--Guava clones 143 and 168 had been

FIGURE 4. LIFE CYCLE CAGE

FIGURE 5. LEAF PREFERENCE CAGE (DISKS)

observed in the field to differ in the amount of thrips damage (Nakasone, unpublished data). Eighteen leaf disks 2.1 cm in diameter from both clones were embedded in a 150 x 15 mm petri dish in the laboratory at room temperature. Approximately 50 first instar thrips were placed in the dish and it was covered. Approximately the same number of thrips were released in another 150 x 15 mm petri dish which contained ½ leaf of clone 168 and ½ leaf of clone 143 (Fig. 6). Daily counts of thrips and fecal spots on each were made for 3 days. Counts were analysed using chi-square. This test was set up to see if differences in preference observed in the field could be detected by a preference test in the laboratory.

Preference Tests on Leaves of Eleven Clones

A preference test with the 11 clones for which field observations had been made was run to test if apparent differences in preference observed in the field could be detected in a laboratory test. A randomized complete block design with 11 replications was used. One leaf disk 3.2 cm in diameter of each clone was embedded in a 1% agar which had been poured in the lid of a 150 x 15 mm petri dish. Leaf disks were larger than before because only one disk of each clone was placed in the dish rather than 18. A 1% agar medium was used since it was found to work as well as a 2% agar medium but was less expensive. Agar was poured in the lid of the petri dish so the bottom could be pushed into the agar to seal the cage so no thrips could escape. Daily counts were made of thrips and fecal drops per disk.

Preliminary Preference Tests on Fruits

1. Agar versus no agar--The recovery of thrips from whole mature

FIGURE 6. LEAF PREFERENCE CAGE (½ LEAF)

green fruits embedded ½ way in 1% agar in 26.5 x 15.5 x 5 cm plastic containers was compared with the recovery from whole fruits placed without support (no agar) in plastic containers. The fruits were inoculated with 10 first and second instar thrips and the containers were covered with tight fitting lids with hole 9.5 x 3.5 cm covered with cotton organdy to permit escape of the CO_2 produced by the respiring fruits. After 5 days the number of thrips per fruit was counted. The use of fruit embedded in agar was adopted and used in further preference tests since the unsupported fruits often rolled on thrips and squashed them when the cage was being handled, while the agar method provided support for the fruits and a larger edge of the fruit for the thrips to encounter.

2. Mature green versus young fruit--Mature green fruit and young green fruit of 'Beaumont' guava were compared to test if there is any difference in preference of thrips for different age fruits. Ripe fruits were not used since they are more likely to rot under laboratory conditions than green or mature green fruits. Two quarter fruit section 30-35 mm in diameter from mature green fruits (approximately 4 months old) and 2 halves of young green fruits (30 mm in diameter) were embedded in 1% agar with 0.1% benzoic acid to prevent rotting in 150 x 15 mm petri dishes. Each slice was inoculated with 15 first instar thrips. A randomized complete block design with 5 replications was used. Counts were made of the number of thrips per slice after 1 day and compared using chi-square. No differences were found between fruit ages so younger fruits were adopted for testing since they were easier to handle.

Preference Tests on Fruits of Eleven Clones

A preference test on fruits of the 11 clones for which Field observations and leaf preference tests had been made was run to see if fruit preference results would confirm the other two. One young fruit half (30-35 mm in diameter) of each clone was embedded in agar with 0.1% benzoic acid in 26.5 x 15.5 x 5 cm plastic containers (Fig. 7). Each fruit half was inoculated with 15 first and second instar thrips and the containers were covered with tight fitting lids. A randomized complete block design with 6 replications was used. The number of thrips on each fruit were counted 3 days after inoculation.

The four least preferred fruits from the previous experiment were compared with 'Beaumont' and 'Ka hua kula,' 2 commercial cultivars in a similar trial in a randomized complete block design with 9 replications. The four least preferred clones from this trial were also tested alone in a randomized complete block design with 8 replications.

Statistical Transformation

Unless otherwise stated all data were transformed using $\sqrt{x + 1}$ which is necessary to stablilize the variance when many counts are small (Snedecor and Cochran 1967). Transformed means were compared with LSD, Cochran's t' or Duncan's Multiple Range Test (Duncan 1955). Means were retransformed by squaring the transformed mean and subtracting 1.

FIGURE 7. FRUIT PREFERENCE CAGE

RESULTS AND DISCUSSION

Seasonal Abundance of Thrips

The monthly variation of thrips populations on the trees in Field J-1 is shown in Figure 8 and Table 1. Thrips populations were highest between September and January. October was the month with the highest thrips population with January nearly as high. A second peak occurred in May but it was considerably lower than the peak between September and January. There was a 20-fold increase in population from August to October (Table 1).

No dead or defoliated trees were observed. Only a few trees supported high enough thrips populations (Table 2, Figs. 9, 10) to cause some silvering of leaves and scarring of fruits (Figs. 11, 12). Since severe thrips infestations in guava cause fruit russetation and defoliation (Smith, 1953) and have even caused the death of wild guava stands (Urich, 1928), the level of infestation at this time at Waimanalo was considered to be light.

Relationship of Seasonal Abundance and Environment

There was no correlation between average maximum or minimum monthly temperatures with monthly thrips totals on either all 132 trees (Fig. 8) or on the 6 most highly infested progenies (Trees 143-10, 143-11, 148-2, 188-2 and 143-9) (Table 2, Fig. 13). Temperature is one of the two most important environmental factors affecting thrips populations (Lewis 1973). Cooler temperatures would more likely be limiting to Waimanalo since red-banded thrips is a species which developed in the warm tropics. However, the lack of correlation between thrips population

TABLE 1

MONTHLY THRIPS ON PROGENIES OF 11 GUAVA CLONES AND A COMPARISON OF HALF-SIB FAMILIES WHEN INFESTATION IS HIGHEST (OCTOBER)

Monthly Thrips Total on 20 Leaves/Tree for 12 Trees/Family														Comparison of October Mean No. of Thrips/Leaf[a]	
	1975										1976				
Family	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Tot	Means	Duncan's Multiple Range*
180	7	6	1	1	1	1	2	4	12	7	11	4	57	0.02	Light infestation
156	2	0	4	3	2	5	8	8	21	20	69	12	154	0.02	
168	0	2	12	4	0	0	3	10	17	25	87	14	174	0.04	
176	0	19	18	14	4	2	6	11	18	25	12	6	135	0.04	
196	7	26	9	2	6	3	0	11	11	8	15	12	110	0.04	
132	0	2	2	4	4	1	1	13	42	49	73	8	199	0.04	
159	6	2	22	3	3	5	17	17	9	32	77	28	221	0.06	
157	0	59	21	95	39	2	4	93	50	170	143	21	697	0.23	Heavy infestation
188	1	4	6	4	1	1	37	184	96	101	139	17	591	0.46	
148	43	6	28	29	64	5	103	319	95	60	289	28	1069	0.80	
143	53	130	308	98	35	28	182	430	185	191	130	33	1803	1.10	
Tot	119	256	431	257	159	53	363	1100	556	663	1045	183			

a Means and multiple range test were calculated only for the October data and do not apply to the other months.

* All means underscored by the same line are not significantly different at the 95% level.

TABLE 2

MEAN NO. OF THRIPS PER LEAF ON GUAVA TREES IN OCTOBER

TREES	MEANS	DUNCAN'S MULTIPLE RANGE 5%
74 trees[a]	0.00	Light infestation
13 trees[b]	0.04	
10 trees[c]	0.08	
168-12	0.10	
6 trees[d]	0.12	
3 trees[e]	0.17	
148-8	0.19	
148-9	0.23	
2 trees[f]	0.30	
196-3	0.32	
132-3	0.34	
159-3	0.37	
188-4	0.39	
157-11	0.42	
148-7	0.46	
148-12	0.49	
188-1	0.69	
143-1	0.82	
2 trees[g]	0.90	
2 trees[h]	1.31	Heavy infestation
143-12	1.37	
157-7	1.53	
143-9	2.96	
188-2	3.37	
148-1	4.15	
148-2	4.76	
143-11	5.15	
143-10	7.53	

* All means underscored by the same line are not significantly different.

a. 132- 2, 4, 5, 6, 7, 9, 10, 12; 143- 2, 3, 4, 6; 148- 4, 11; 156- 1, 2, 3, 5, 6, 7, 8, 9, 10, 12; 159- 1, 2, 4, 5, 8; 168- 1, 4, 5, 6, 8, 10, 11; 176- 1, 2, 4, 7, 8, 10, 11, 12; 180- 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12; 188- 5, 8, 9; 196- 2, 4, 5, 6, 7, 9, 10, 11, 12; 157- 1, 4, 6, 8, 9, 10, 12.

b. 132- 11; 143- 7; 156- 4; 157- 5; 159- 6, 7, 11, 12; 168- 7, 9; 176- 9; 188- 11; 196- 8.

c. 132- 8; 143- 8; 148- 3; 159- 9, 10; 168- 3; 176- 5; 188- 7, 12; 196- 1.

d. 132- 1; 143- 5; 157- 3; 168- 2; 176- 6; 188- 10.

e. 148- 6; 176- 3; 180- 1.

f. 148- 5; 156- 11.

g. 188- 3, 6.

h. 148- 10; 157- 2.

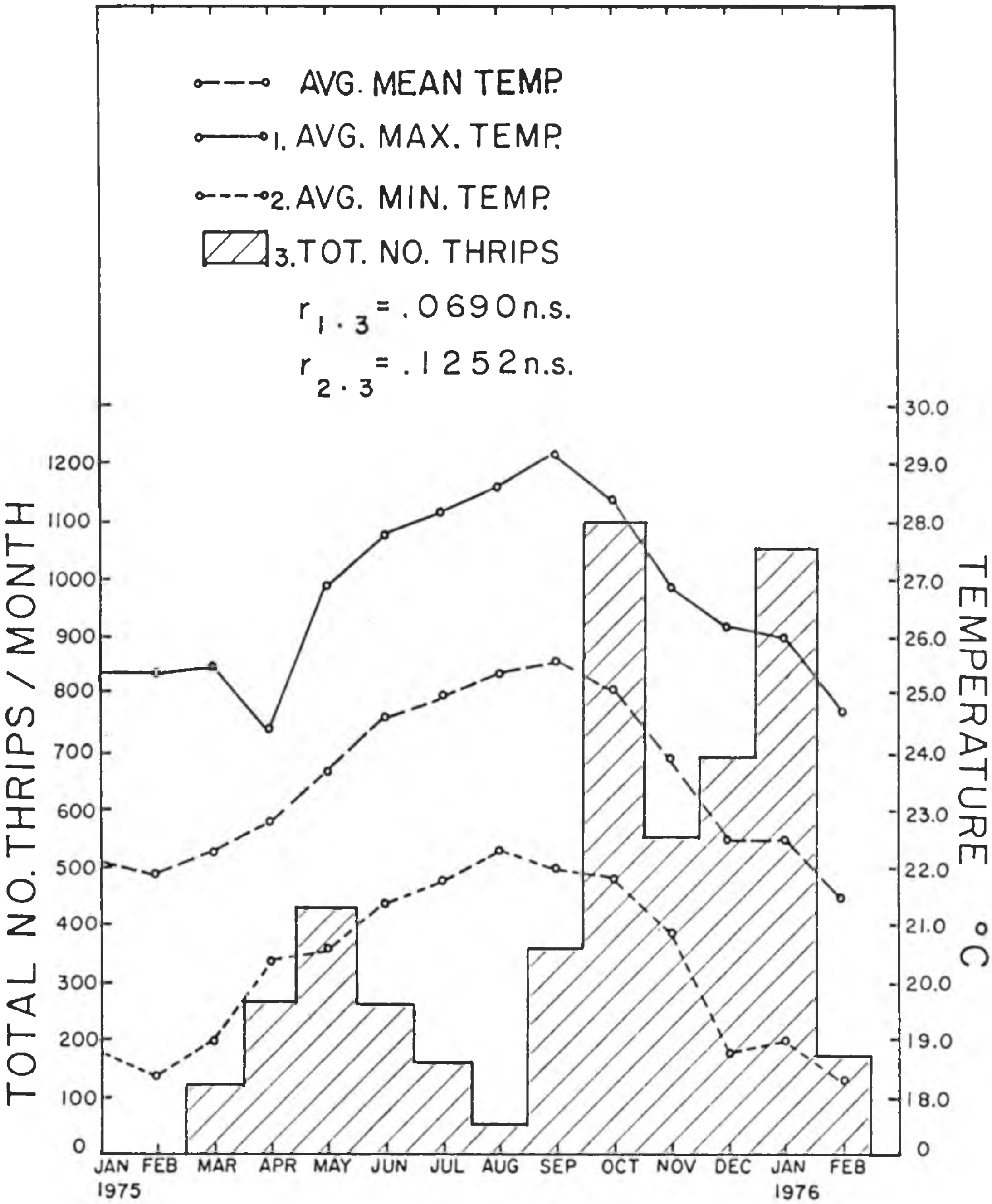

FIGURE 8. TOTAL MONTHLY THRIPS POPULATION ON 132 GUAVA TREES AND MONTHLY AVERAGE MAXIMUM, AVERAGE MINIMUM, AND MEAN TEMPERATURES

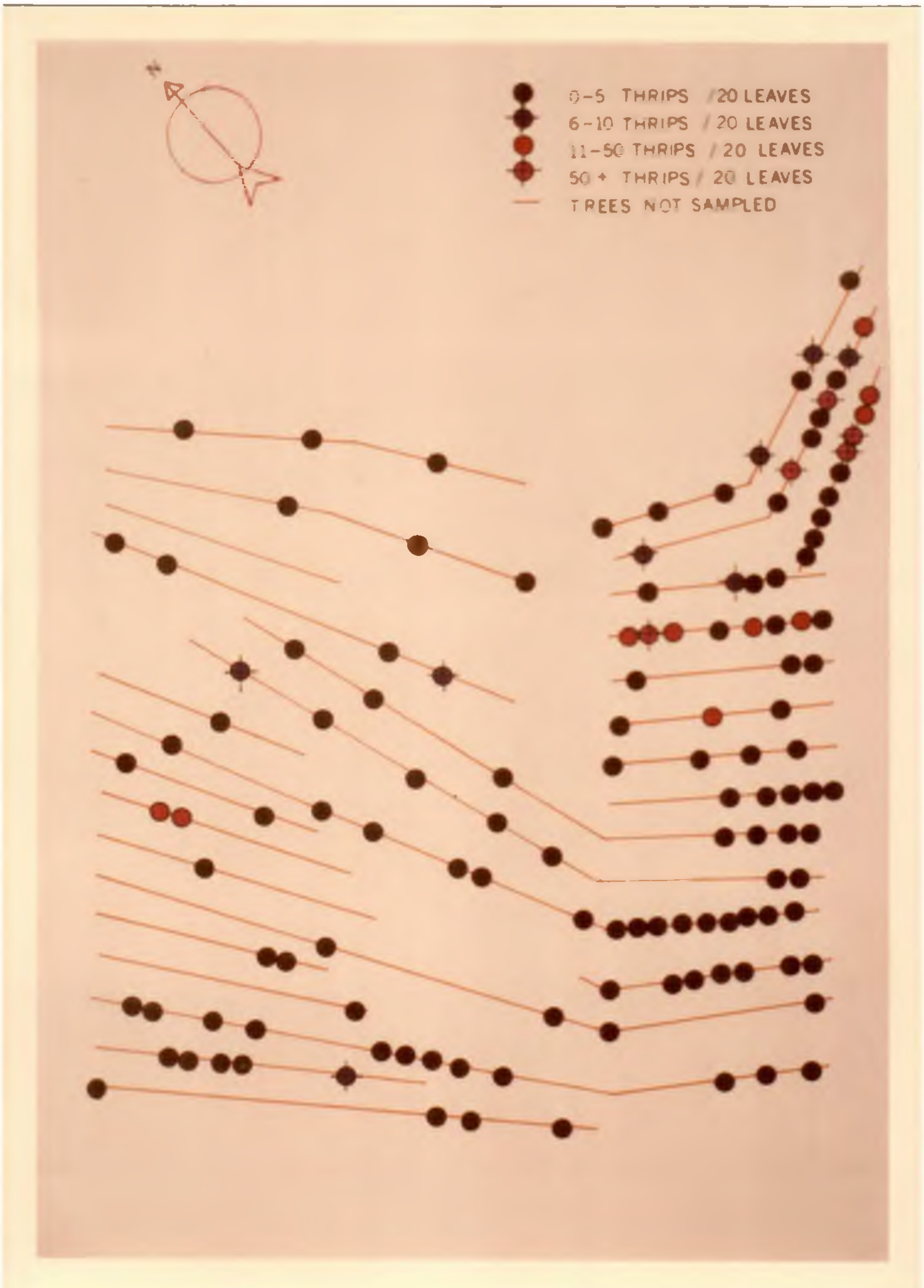

FIGURE 9. SPATIAL DISTRIBUTION OF THRIPS IN PROGENY FIELD DURING OCTOBER 1975

FIGURE 10. SPATIAL DISTRIBUTION OF THRIPS IN PROGENY FIELD DURING MAY 1975

FIGURE 11. LEAF SILVERING DAMAGE IN THE FIELD

FIGURE 12. FRUIT AND LEAF DAMAGE IN THE FIELD

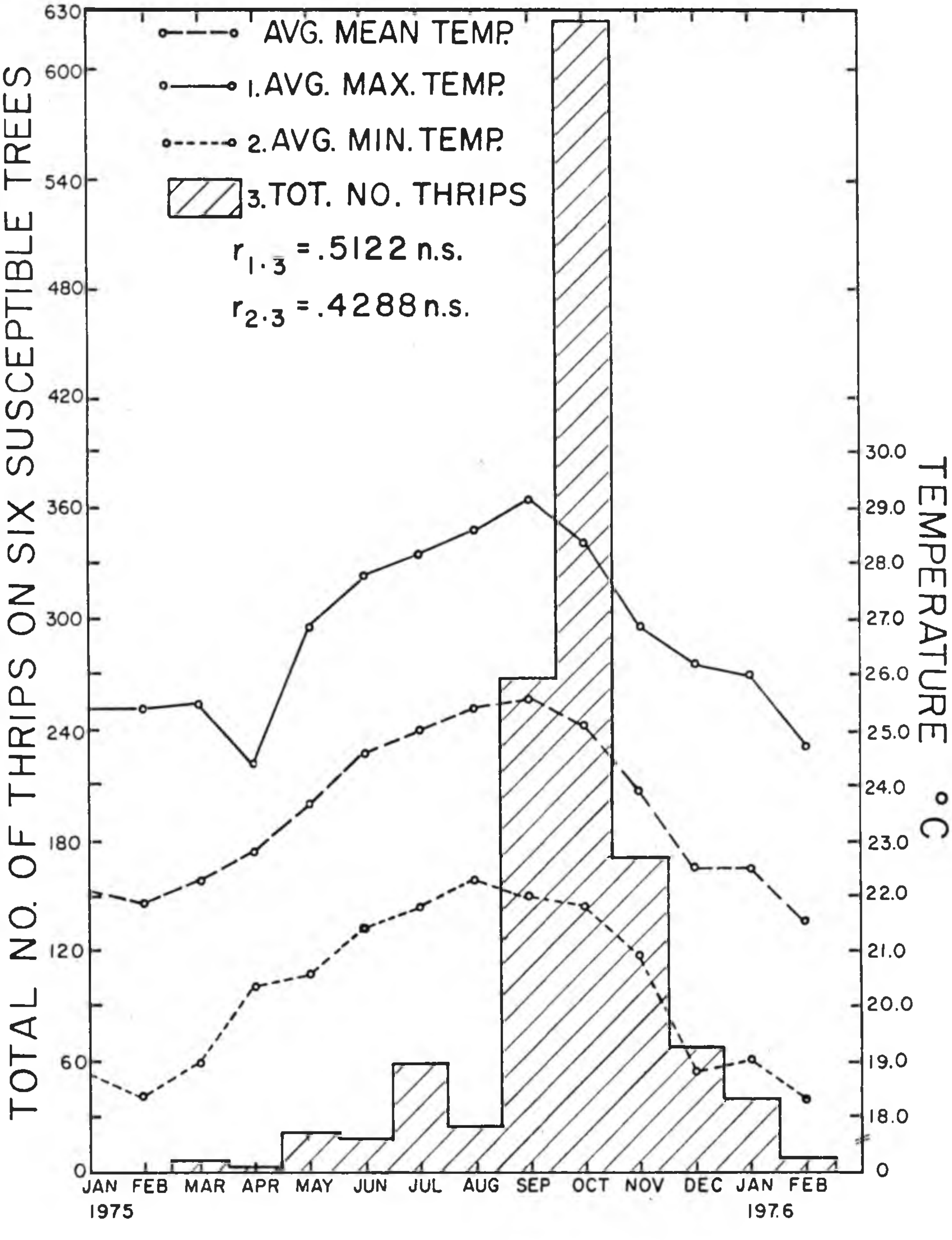

FIGURE 13. TOTAL MONTHLY THRIPS POPULATION ON THE 6 MOST SUSCEPTIBLE TREES (TABLE 2) AND MONTHLY AVERAGE MAXIMUM, AVERAGE MINIMUM, AND MEAN TEMPERATURES

levels and temperature seems to indicate that temperature was not a limiting factor at this experimental site.

There was no correlation between total monthly rainfall and monthly thrips totals on either all 132 trees or on the 6 most highly infested trees (Figs. 14, 15). The total rainfall at the Waimanalo Experimental Farm during the 12 months of this study was 766 mm, compared to the average of 991 mm for the last 7 years (U. S. Weather Bureau 1970-1976). However, there were 9 days which had more than 25 mm (Table 13). Four of these days occurred in February 1976 and may have been the cause of the drastic drop in the thrips populations from the previous month. Four consecutive days of heavy rainfall, totalling 216 mm on November 24-27, 1975 fell just prior to the usual sampling date at the end of the month and may have caused the drop from October. Heavy or sudden rain showers can wash thrips from exposed leaves (Lewis 1973, Russell 1912). Except for these two months when rainfall may have caused a decline in the thrips populations rainfall did not seem to be a factor affecting the thrips population levels.

The multiple correlation between the average minimum monthly temperature, the total monthly rainfall and the monthly thrips population for the 6 most highly infested trees was not significant ($r = .2155$). Therefore, the low level of thrips infestations cannot be attributed to temperature or rainfall or a combination of them.

The near by location of more preferred plant hosts may have been one cause of low thrips populations on the guavas. Tropical almond, mango, and macadamia which are reported hosts for the red-banded thrips (Reyne 1921, Cooperative Economic Insect Reporter 1974) and cashew which was reported to be preferred over guava by the red-banded thrips

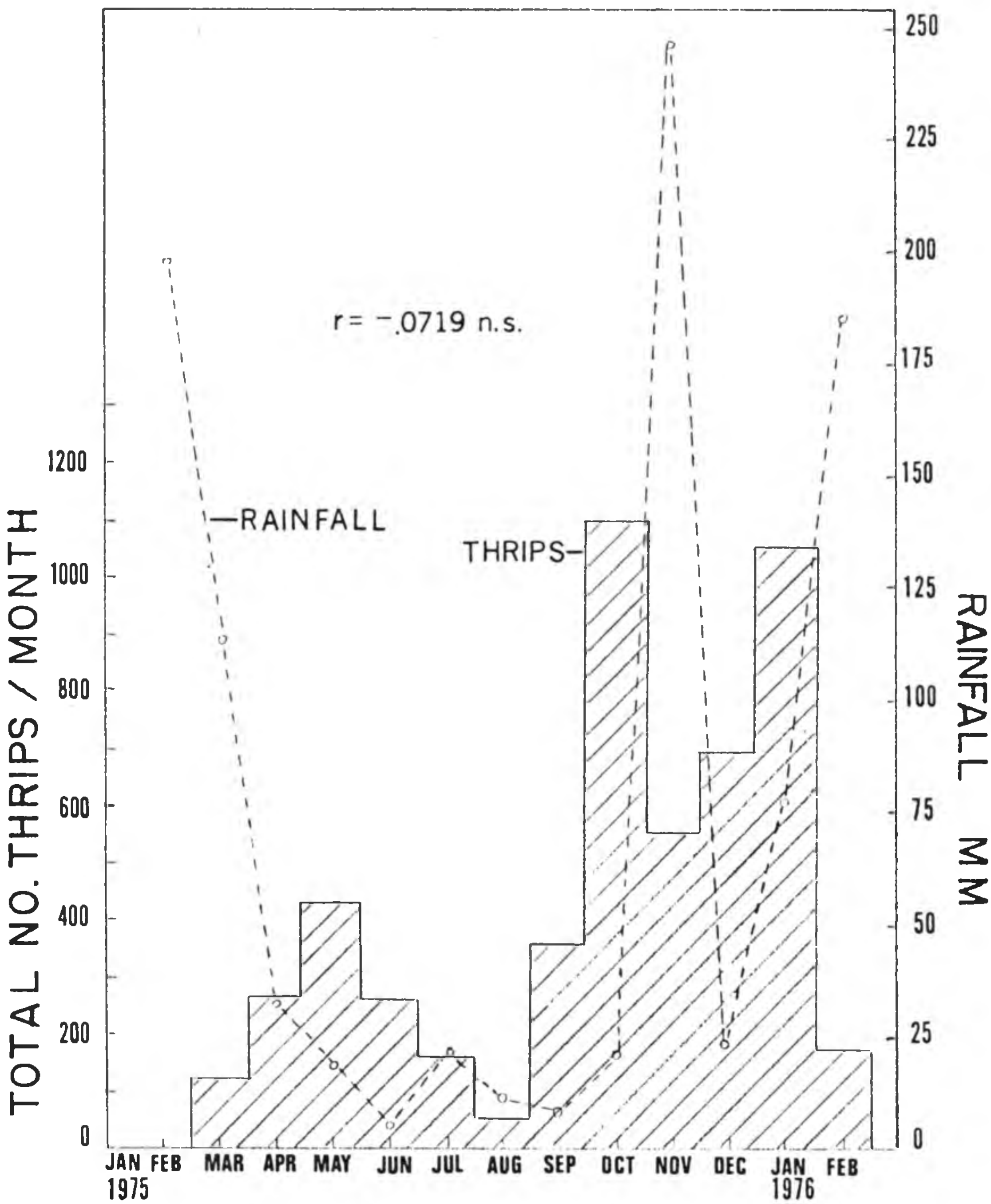

FIGURE 14. TOTAL MONTHLY THRIPS POPULATION ON 132 GUAVA TREES AND TOTAL MONTHLY RAINFALL

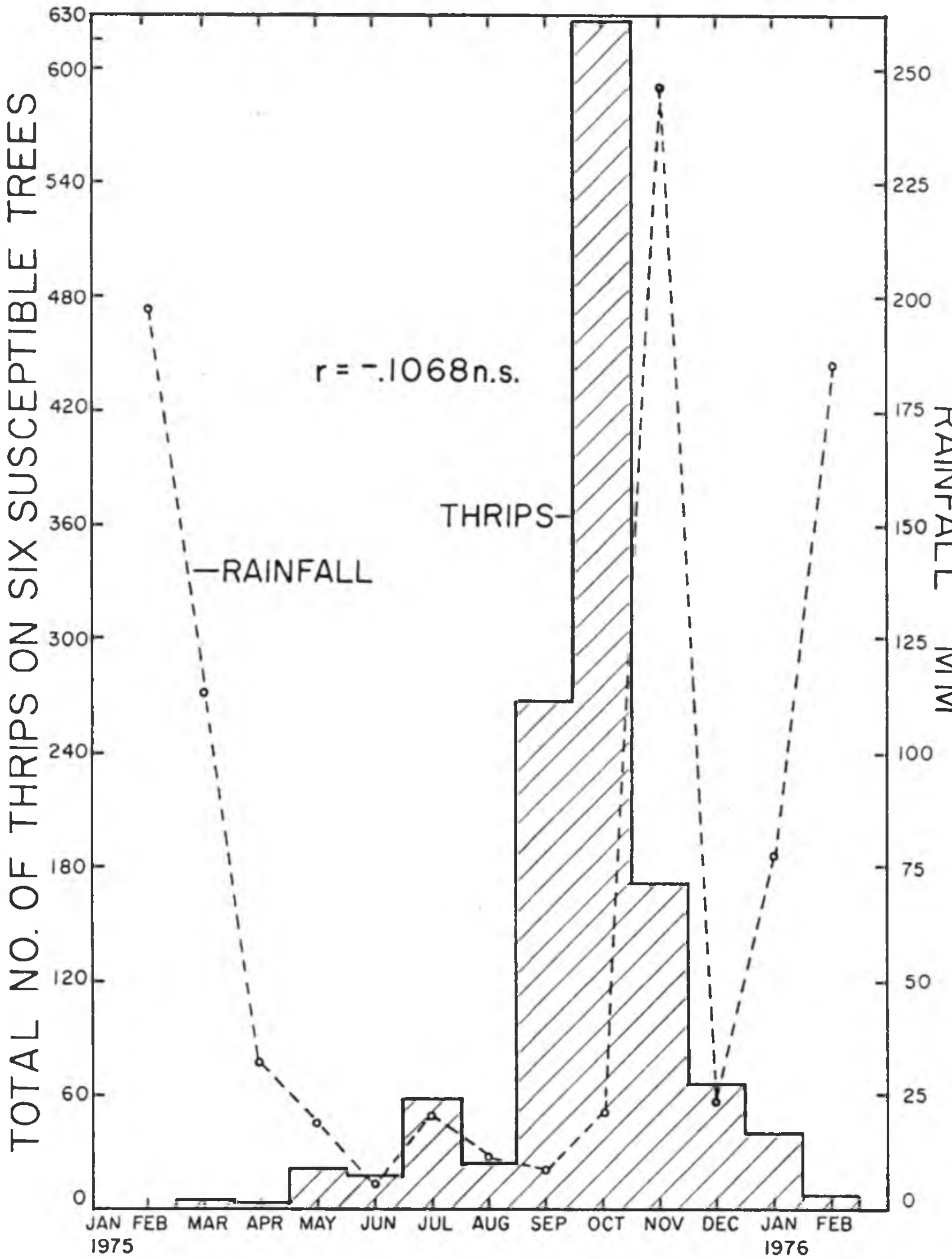

FIGURE 15. TOTAL MONTHLY THRIPS POPULATIONS ON THE 6 MOST SUSCEPTIBLE GUAVA TREES (TABLE 2) AND TOTAL MONTHLY RAINFALL

(Ananthakrishnan and Muraleedharan 1974) are found in close proximity to the guava fields. The tropical almond tree which was used as the source of thrips for this study sometimes had a very severe infestation when the infestation on guava was light.

Poor fruit production may have been another factor keeping the thrips population low during the period of this study. Fennah (1963) showed that the peak of thrips population numbers on cashew in Trinidad concided with the period of fruit maturity. Fruit production was observed to be low on these trees during this period, although no records were kept. The peaks in thrips population in October to January with a second lower peak in May do coincide almost exactly with peaks of fruit production in Hawaii (Nakasone et al 1976).

Mitchell (1973) reported that natural enemies such as fungi and predators usually keep the red-banded thrips on guava under fair control even though occasional outbreaks do occur. However, in this study no fungi were observed in the field and the number of predators observed was so minimal that it was deemed unnecessary to report them. Thus, natural enemies were not felt to be the cause of the low thrips populations on guava.

Spatial Distribution of Thrips in Progeny Field

Figures 9 and 10 show the spatial distribution and concentration of thrips in the field during October and May of 1975. In both months thrips were heavily concentrated in a limited number of trees in a definite area of the field. In May the highest concentration was in the middle of the western edge of the field. Even though there was a high concentration in this same area in October the highest concentration of thrips was in the eastern corner.

The spatial distribution of thrips in the field was probably not due to a normal random distribution of the population. A highly significant correlation between Nakasone's previous ratings (Nakasone, unpublished data) of these trees with the 12 month totals for the same trees in this study, show that thrips population build up in the same trees and the same areas of the field over a period of years. The distribution is probably due to the tendency thrips have to aggregate in distinct microhabitats which provide the most favorable, food, shelter and sites of reproduction (Lewis 1973). In the field it is possible to identify the most susceptible trees since they have the highest infestation but the trees with few or no thrips are not necessarily resistant, even when field populations are high (Callan 1943a). Therefore, laboratory tests are necessary for identifying resistant trees.

Half-Sib Families Show Different Levels of Infestation

There were some differences between half-sib families in October, mostly among the more highly infested ones (Table 1). The relative ranking for the whole year was similar to that in October. Since the differences, though slight, seem to persist for the whole period, it can be inferred that these differences are genetic and may have been inherited from the common female parent. Clones 143 and 148 which produced the most highly infested progeny had also been noticed to support high levels of thrips by Nakasone (unpublished data).

Levels of Infestation on 7-Year Old Clonal Trees

Only 'Beaumont' was significantly different from the other 10 trees tested (Table 3). 'Beaumont' had a higher level of infestation than the other trees. The differences in infestation previously noted by Nakasone (unpublished data) were not detected. The reason was probably the very low level of thrips infestation.

Many fewer thrips were found on these 7-year old trees in Field J-1 than on 3-year old trees in Field J-2 (Tables 1, 3). This was most likely due to the much greater tree density and different growth habits in the 3-year old field than in the 2-year old field (see Materials and Methods). The 3-year old trees apparently provided a more preferable microhabitat for thrips than did the 7-year old trees.

Thrips Survival on Two Trees Which Differed in Susceptibility

The results of the obligatory food tests on a possibly susceptible and a possible resistant sister trees are presented in Table 4. In August-September, when only leaves were tested, there was a significant difference between the two trees. In October-November, when both leaves and fruits were tested, there were no differences between trees. The level of survival on the leaves of both trees in October-November was the same as that of the possibly resistant tree in August-September. The level of survival on the fruits of both trees at this time was relatively high and significantly different from the level of survival on the leaves at that time. In summary, in August-September, the leaves of 156-4 showed high survival, 156-9 showed low survival, and fruits were not tested. In October-November leaves of both trees showed low survival, while fruits of both trees showed high survival.

The trees were fruiting in October-November but not in August-

TABLE 3

COMPARISON OF THE MEAN NUMBER OF THRIPS PER LEAF SAMPLED IN 2 REPLICATIONS OF 11 GUAVA TREES ONCE A MONTH FOR 8 MONTHS (JULY '75-FEB. '76)

Mean No. of Thrips / Leaf / 8 Months	
Trees	Means*
168	0.004
156, 196	0.007
157, 159	0.010
176, 180	0.012
148	0.016
143	0.038
132	0.048
Beaumont	0.150

* All means underscored by the same line are not significantly different at the 95% level with Duncan's Multiple Range Test.

TABLE 4

NUMBER OF THRIPS ALIVE AFTER 30 DAYS IN ANTIBIOSIS TESTS ON 2 GUAVA TREES

Comparison Between Trees

Treatment	Mean No. of Thrips Per Leaf						Mean No. of Thrips Per Fruit		
	Aug-Sept			Oct-Nov			Oct-Nov		
	156-4	156-9	LSD	156-4	156-9	LSD	156-4	156-9	LSD
20 Thrips	39.25	4.00	4.65*	4.00	1.00	1.35 ns	39.25	49.25	3.28 ns
10 Thrips	32.75	2.50	1.44*	1.50	0.50	0.82 ns	17.75	30.50	0.88<3.20[a]ns
5 Thrips	49.00	4.25	4.55*	7.75	0.00	1.00<3.20[a]ns	12.25	7.00	3.35 ns

Comparison Within Trees - Fruit vs. Leaves, Oct-Nov

Treatment	Tree 156-4 Mean No. of Thrips			Tree 156-9 Mean No. of Thrips		
	Fruit	Leaf	LSD	Fruit	Leaf	LSD
20 Thrips	39.25	4.00	3.12*	49.25	1.00	4.10>3.20[a]*
10 Thrips	17.75	1.50	3.44 ns	30.50	0.50	0.19*
5 Thrips	12.25	7.75	2.68 ns	7.00	0.00	1.00<3.20[a]ns

Comparison Between Periods

Treatment	Tree 156-4 Mean No. of Thrips			Tree 156-9 Mean No. of Thrips		
	Aug-Sept	Oct-Nov	LSD	Aug-Sept	Oct-Nov	LSD
20 Thrips	39.25	4.00	3.77*	4.00	1.00	1.14 ns
10 Thrips	43.75	1.50	0.93*	2.50	0.50	1.15 ns
5 Thrips	49.00	7.75	2.71 ns	4.25	0.00	1.00<3.20[a]ns

* Indicates significant differences at the 95% level.
a Comparisons made using Cochran's t'. In all other cases LSD is used to compare means.
ns Means not significantly different.

September. Adequate food for thrips may have been diverted from the leaves to the developing fruits, rendering the leaves of the susceptible 156-4 now unable to support the thrips. This phenomenon was also observed by Fennah (1963) who found red-banded thrips on developing cashew fruits and not on leaf petioles on the same branch. He explained this by the fact that the developing fruit is the storage organ which receives not only the introgenous and other nutrient-rich compounds taken up through the roots but also to a greater or less extent, those mobilized and exported from adjacent leaves. Since the fruits on both trees support the same high population level any resistance present in 156-9 is apparently expressed only by the leaves.

Correlation Between Number of Thrips and Damage

The initial number of thrips was positively and significantly correlated with damage (percent surface area of leaf 'silvered' or fruit scarified) in all cases (Table 5). The final number of thrips found was also positively and significantly correlated with damage in all cases but one. The correlation between final number of thrips with damage on leaves of tree 156-4 during the October-November period was non-significant.

Since the thrips were caged on the leaf or fruit, they had to feed or die. Since most of the correlations of damage and initial thrips population were higher then the correlations of damage and final thrips population, it seems that the initial thrips populations attempted to feed and caused the damage that was measured, even if the food source was inadequate and the thrips were not able to survive. This difference in the correlations between damage and initial or final thrips

TABLE 5

CORRELATION OF INITIAL AND FINAL NO. OF LIVE THRIPS WITH PERCENT DAMAGE IN OBLIGATORY FOOD EXPERIMENTS ON 2 GUAVA TREES

		Aug 11 - Sept 15, 1975				Oct 23 - Nov 21, 1975							
		Leaves 156-9		Leaves 156-4		Leaves 156-9		Leaves 156-4		Fruits 156-9		Fruits 156-4	
Rep.	Initial No. of Thrips	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage
A	0	0	0	0	0	0	0	0	0	0	0	0	0
B		0	0	0	0	0	0	0	0	0	0	0	0
C		0	0	0	0	0	0	0	0	0	0	0	0
D		0	0	0	0	0	0	0	0	0	0	0	0
A	1	2	15	5	10	0	0	0	0	0	0	0	0
B		0	1	15	5	0	0	0	0	0	0	11	20
C		3	5	1	1	0	0	0	0	0	0	1	35
D		0	5	6	1	0	5	0	0	0	0	0	0
A	5	10	40	110	90	0	0	14	1	0	10	0	10
B		5	10	46	70	0	10	13	10	7	32	20	45
C		2	1	10	1	0	0	4	5	5	25	22	50
A	10	7	40	57	100	0	0	1	2	24	25	0	50
B		3	50	36	35	0	0	1	10	32	75	13	60
C		0	1	37	35	2	1	4	1	35	35	19	30
D		0	10	45	70	0	20	0	0	31	55	39	60

TABLE 5. (Continued) CORRELATION OF INITIAL AND FINAL NO. OF LIVE THRIPS WITH PERCENT DAMAGE IN OBLIGATORY FOOD EXPERIMENTS ON 2 GUAVA TREES

		Aug 11 - Sept 15, 1975				Oct 23 - Nov 21, 1975							
		Leaves 156-9		Leaves 156-4		Leaves 156-9		Leaves 156-4		Fruits 156-9		Fruits 156-4	
Rep.	Initial No. of Thrips	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage	Final No. of Thrips	Percent Damage
A	20	7	60	34	100	1	0	4	50	77	90	73	95
B		3	60	2	80	0	11	0	5	45	95	14	60
C		6	5	47	80	1	15	11	20	50	95	54	70
D		0	60	74	75	2	35	1	10	25	70	16	25
Correlation Initial No/ % Damage		.71695**		.79071**		.50424*		.65309**		.95128**		.77262**	
Correlation Final No/ % Damage		.50165*		.73741**		.53192*		.30086		.90519**		.81947**	

* Correlation significant at the 95% level

populations are most noticeable in the trials in which the thrips did not survive, leaves of 156-9 in August-September, and leaves of both trees in October-November. When the thrips survived and multiplied, the correlation was high between damage and final thrips number, as well as with initial thrips number. Therefore, it is concluded that damage ratings are not a good way to evaluate any possible antibiosis in this test. However, under natural field conditions damage rating may be expected to be correlated with thrips infestations since thrips will not be forced to feed on unpalatable food sources.

Suggested Field Selection Techniques

The selection of resistant trees in the field by visual ratings or sampling populations is not adequate, since trees with little or no damage or few or no thrips maybe escapes, therefore further laboratory and greenhouse testing of these apparently resistant trees is necessary. A visual rating of trees during a severe infestation is probably the best method for selecting apparently resistant trees. When field populations are low sampling populations will probably be more accurate.

Life Cycle Duration

Figure 16 shows an excised red-banded thrips egg. The duration of the first instar was 4.4 ± 0.5 days (Table 6, Figs. 17, 18); the second instar was 8.4 ± 1.7 days (Fig. 19); the prepupal stage was 1.2 ± 0.2 days (Fig. 20); and the pupal stage was 2.8 ± 0.5 days (Fig. 21). Figure 22 shows adult females in a colony with prepupae and pupae.

The duration of the life cycle on guava leaves found in this study is comparable to the duration of the life cycle as reported by Russell (1912) and Reyne (1921) on other host plants. Thus, it can be concluded

TABLE 6

DURATION OF THE LARVAL AND PUPAL STAGES OF THE RED-BANDED THRIPS

	First Instar	Second Instar	Prepupa	Pupa
Mean No. of Days Duration	4.4±0.5	8.4±1.7	1.2±0.2	2.8±0.5
No. of Thrips Observed	44	24	23	21

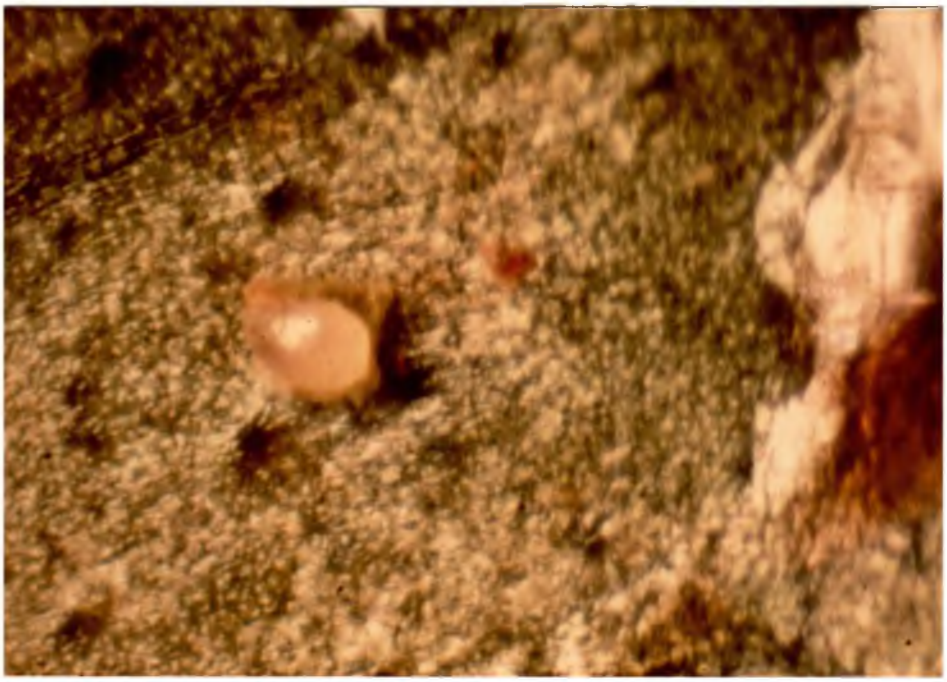

FIGURE 16. EGG (80)

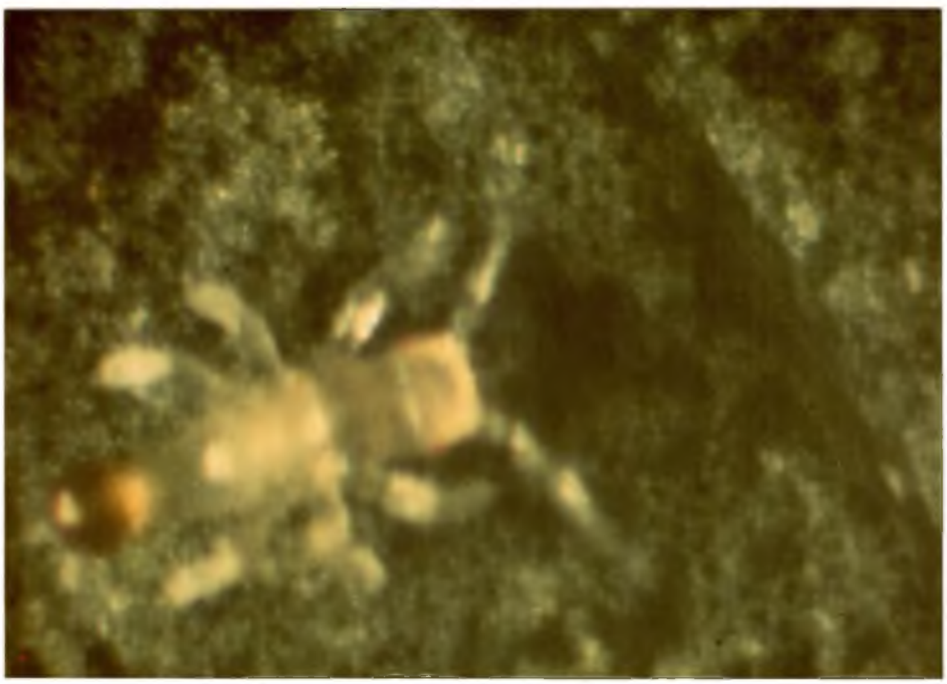

FIGURE 17. ONE DAY-OLD FIRST INSTAR THRIPS (240X)

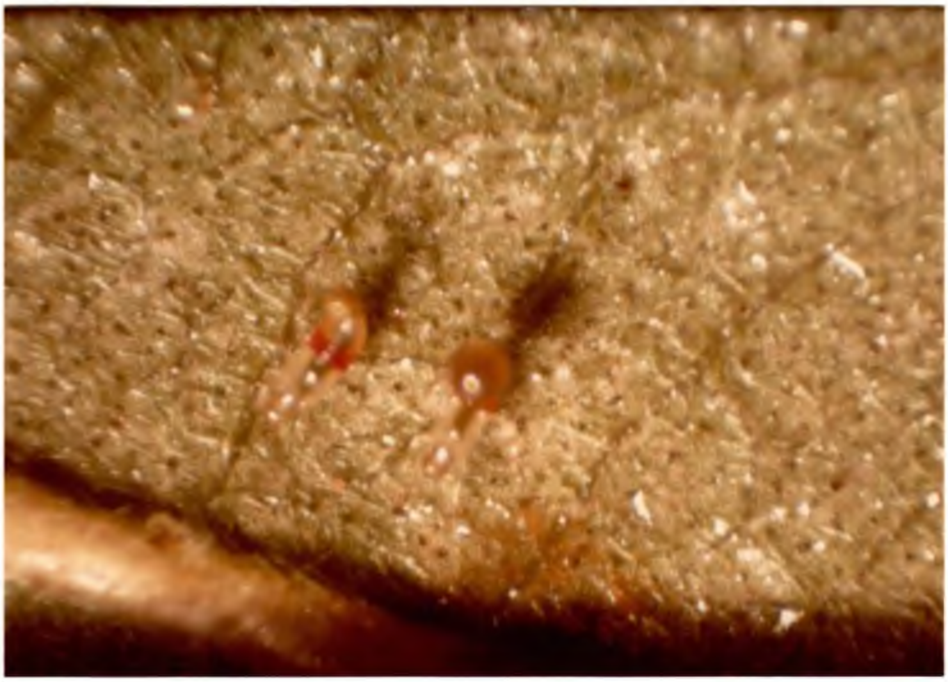

FIGURE 18. THREE DAY-OLD FIRST INSTAR THRIPS (40X)

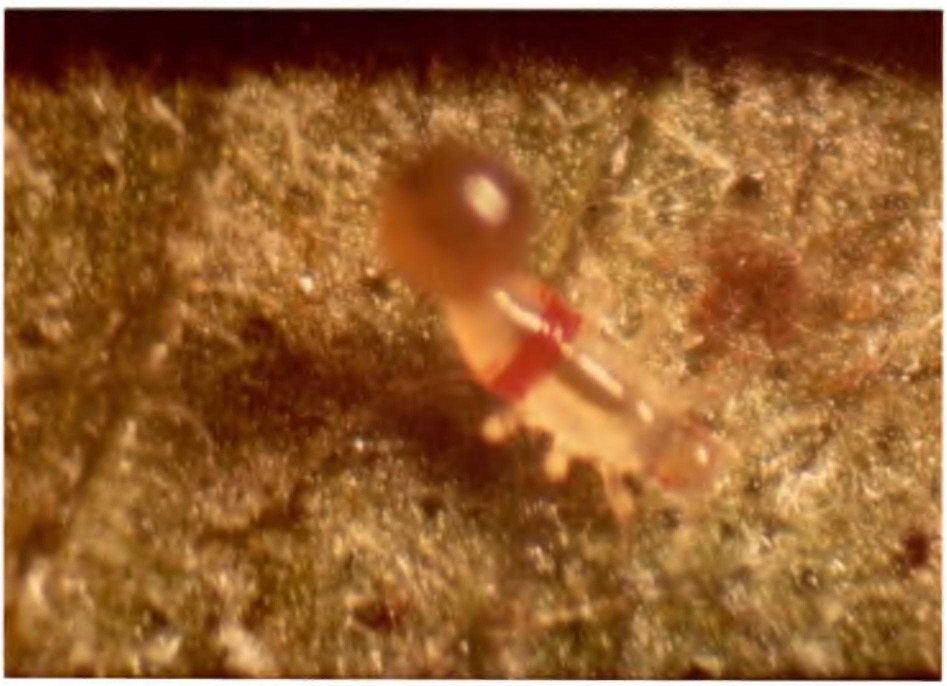

FIGURE 19. SECOND INSTAR THRIPS (60X)

FIGURE 20. PREPUPAL STAGE (70X)

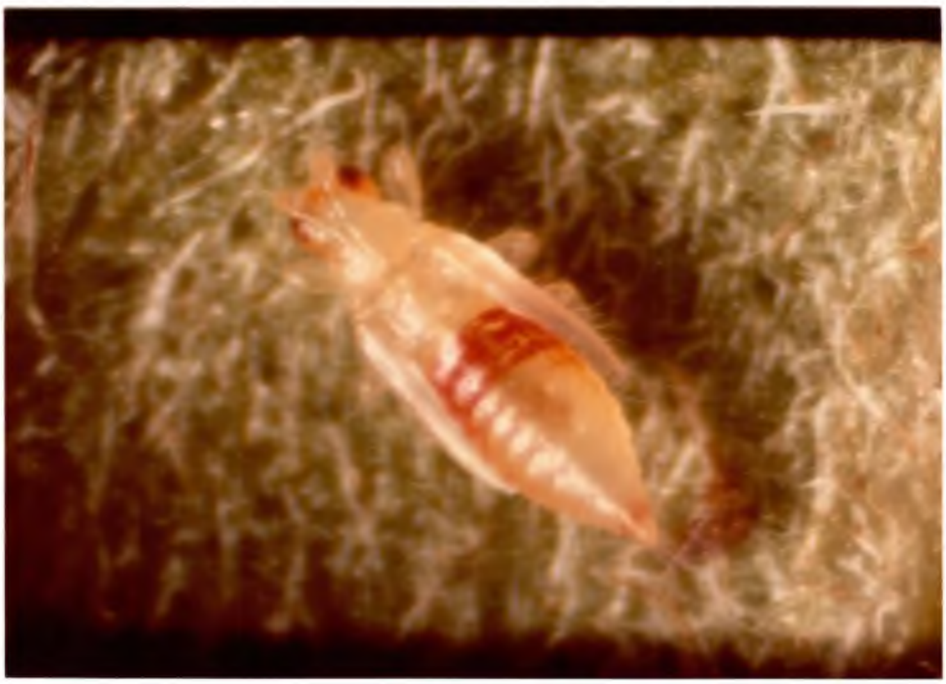

FIGURE 21. PUPAL STAGE (70X)

FIGURE 22. ADULTS IN A COLONY (15X)

that the food quality of the cultivar 'Beaumont' provides reasonable nutrition for the thrips. Russell (1912) and Lewis (1973) have reported that warmer temperatures speed up the life cycle of the red-banded thrips. Therefore, it seems likely that the life cycle would be shorter in the field since the temperature in the field is generally higher than that in the laboratory (Table 14).

More than half of the thrips died during the course of this experiment (Table 6). This may have been caused by the fungal-like growth observed first on the legs of the thrips and later on other parts of their body. It is possible that the thrips were weakened by the fungus, and the life cycle was consequently prolonged.

Preference Between Species

The red-banded thrips strongly preferred cashew leaves over guava leaves (Table 7). The results agree with the findings of Ananthakrishnan and Muraleedharan (1974), so it was concluded that the test probably could be used for detecting thrips preference among different guava geno-types.

Preference Between an Apparently Resistant and an Apparently Susceptible Clone

The thrips showed a stronger preference for the more susceptible clone 143 than for the more resistant clone 168 (Table 8). These results gave further evidence that this laboratory preference test can be used to detect differences in thrips preference. The number of thrips on clone 168 dropped while the number on clone 148 grew from 1 day until 3 days after inoculation. This appears to show that clone 168 was not as desirable a food source as clone 143. Fecal spots,

TABLE 7

NUMBER OF THRIPS/LEAF DISK OF GUAVA AND CASHEW WITH CHI-SQUARE AND PROBABILITY VALUES

Two Days After Inoculation

Replication	No. of Thrips on Guava	No. of Thrips on Cashew	Chi-Square	df	Probability
A	20	41	7.23	1	.01 - .001
B	17	38	8.02	1	.01 - .001
Totals	37	79	15.25	2	

Source:	Chi-Square	Degrees of Freedom	Probability
Totals	15.25	2	
Summed Data	15.21	1	$<$ .001
Homogeneity	0.04	1	.90 - .70

TABLE 8

THE PREFERENCE FOR CLONES 168 AND 143 EXHIBITED BY THE RED-BANDED THRIPS AS INDICATED BY THE NUMBER OF THRIPS AND FECAL SPOTS

Days After Inoculation	Clone 168	Clone 143	Chi-Square	df	Probability
		Thrips/Clone			
1	8	24	8.00	1	.01 - .001
2	2	32	26.47	1	< .001
3	0	49	48.02	1	< .001
		Fecal Spots/Clone			
1	0	0	0.00	0	0.000
2	1	21	18.18	1	<.001
3	5	30	17.85	1	<.001

which are evidence of feeding, were significantly greater on clone 143 than on 168. This again supports the observation that clone 143 was a more preferable food source than clone 168. Total number of fecal spots per clone at the end of 2 and 3 days is significantly correlated (r = 1.00), respectively. This indicates that fecal spots as well as the number of thrips is a good indicator of thrips preference. Since it is easier to count fecal spots than thrips, fecal spots should be used as the index in the future. If quick results are desired then thrips may be counted 1 day after inoculation.

Preference for Leaves of Clones

Data in Table 9 show that the leaves of clones 143 and 148 are the most susceptible. 'Beaumont' and clone 196 were the next most susceptible. Leaves of clones 180, 168, 132, 156, and 157 were the most resistant. These differences were due to preference, but the specific mechanisms involved are not known.

Preference For Fruits of Clones

Data in Table 10 show that fruit of clones 180 and 157 were significantly different from the fruits of clone 132, but the remaining 8 clones were not significantly different from any of the clones. Four clones from this experiment were tested along with 'Beaumont' and 'Ka hua kula,' the other commercial cultivar. Only 'Beaumont' differed significantly (Table 11) and was the most susceptible. When the 4 clones which had the fewest number of thrips in the previous experiment were tested together, they were further separated into least and most preferred groups (Table 12). Clone 157 was the least preferred and clones 168 and 180 were the most preferred. The results of the three experiments

TABLE 9

MEAN NUMBER OF FECAL SPOTS PER LEAF DISK IN A LABORATORY PREFERENCE TEST OF 11 GUAVA CLONES 7 DAYS AFTER INOCULATION

Clones	Mean No. of Spots/Disk*
180	2.3
168	2.4
132	2.7
156	3.1
157	3.6
159	7.4
176	8.1
196	9.3
Beaumont	9.8
148	15.2
143	19.4

* All means underscored by the same line are not significantly different at the 95% level as demonstrated by Duncan's Multiple Range Test.

TABLE 10

FRUIT PREFERENCE AMONG 11 CLONES USING YOUNG GREEN FRUITS

Clones	Mean No. of Thrips/Fruit*
180	5.86
157	6.13
148	7.35
196	8.92
176	9.89
168	10.76
156	14.68
143	14.68
Beaumont	16.47
159	16.81
132	18.36

* All means underscored by the same line are not significantly different at the 95% level as demonstrated by Duncan's Multiple Range Test.

TABLE 11

FRUIT PREFERENCE AMONG 6 CLONES

Clones	Mean No. of Thrips/Fruit*
180	6.18
157	6.95
148	7.82
168	7.94
Ka hua kula	11.32
Beaumont	20.62

* All means underscored by the same line are not significantly different at the 95% level as demonstrated by Duncan's Multiple Range Test.

TABLE 12

FRUIT PREFERENCE AMONG 4 GUAVA CLONES

Clones	Mean No. of Thrips/Fruit*
157	7.79
148	8.34
168	12.98
180	13.98

* All means underscored by the same line are not significantly different at the 95% level as demonstrated by Duncan's Multiple Range Test.

seem to be somewhat contradictory and confusing since significant differences are found between clones 157 and 180 in Table 12, while there are no significant differences detected between these two clones in Tables 10 and 11. Based on the findings in all 3 Tables there seems to be very few significant differences in preference among all the clones. Further research should be carried out to clarify these findings.

Comparison of Laboratory Data with Field Observations

Since there appeared to be very little difference in preference among fruits in the laboratory preference tests only data for leaf preference (Table 9) will be compared with field data (Tables 3, 1) and Nakasone's ratings (unpublished data). Clone 180 was the most resistant in the leaf preference test. It was in the resistant group in the clonal field sampling as well as being the most resistant in Nakasone's rating. Clone 168 was resistant in the leaf preference test; it had the least number of thrips in the resistant group in the clonal field sampling; and was found to be among the resistant group in Nakasone's rating. Clone 132 was resistant in the leaf preference test; it had the highest number of thrips in the resistant group in the colonal field sampling; and was rated resistant by Nakasone. Clone 156 was resistant in the leaf preference test; resistant in the colonal field sampling; and was rated resistant by Nakasone. Clone 157 was resistant in the leaf preference test; resistant in the clonal field sampling; but was rated susceptible by Nakasone. Clone 159 was intermediate in the leaf preference test; resistant in the clonal field sampling; and intermediate in Nakasone's rating. Clone 176 was intermediate in the leaf preference test; resistant in the clonal field sampling; and was intermediate in Nakasone's rating. Clone 196 was susceptible in the leaf preference test; resistant in the clonal field sampling; and was resistant in Nakasone's rating. 'Beaumont' was susceptible in the leaf preference test; the most susceptible in the clonal field sampling; and was also susceptible in Nakasone's rating. Clone 148 was susceptible in the leaf preference test; but it was resistant in the clonal field sampling; and it was also resistant in Nakasone's rating. Clone 143 was the most susceptible in the leaf preference test; resistant in the clonal field sampling; and it was the most susceptible in Nakasone's rating.

The correlation between the mean number of thrips found on leaves of clones in the field (Table 3) with the mean number of fecal spots per clone (Table 9) was non-significant (r = .2212). The correlation between Nakasone's rating of clones with mean number of fecal spots per clone (Table 9) was also non-significant (r = -.4851). On the other hand, the correlation between the total number of thrips found on progenies of clones (Table 1) was highly correlated (r = .8275) with the mean number of fecal spots per clone in the laboratory leaf preference test (Table 9).

The lack of correlation between the clones in the laboratory and the clones in the field is probably due to the low thrips population in the field. Many of those trees with few or no thrips may have been escapes. This would account for the discrepancies between the findings in the field and those in the laboratory. Populations in the seedling trees were found to be much higher than in the clonal trees. This may account for the significant correlation between clones in the laboratory and progeny of clones in the field. According to Painter (1968) cage tests are ordinarily more severe than a field test for resistant varieties because the level of infestation is usually higher. Nevertheless the results from cage tests usually check fairly well with field results. Painter (1968) goes on to state that the validity of cage and greenhouse tests must be checked repeatedly under field conditions. Thus the following steps should be taken to further test the most resistant varieties already identified in the preliminary tests of this study: 1) laboratory antibiosis test; 2) greenhouse preference test; 3) greenhouse antibiosis test; and 4) field test.

SUMMARY AND CONCLUSIONS

A. Sampling Thrips

1. Thrips populations were found to be low and thrips damage was minimal during the year of this study.
2. Prevailing rainfall and temperatures were not correlated with the size of thrips populations.
3. Some susceptible trees were easily identified by sampling but the population pressure was not great enough to be able to identify the most resistant trees. 'Beaumont' was the only susceptible one among the clones sampled, while seedlings of clones 143 and 148 were the most susceptible among the open pollinated progenies of clones sampled.
4. The majority of the thrips population were found to aggregate in a few trees.

B. Obligatory Food Tests

1. Thrips survived and reproduced better on fruits than on leaves.
2. Silvering and russeting were correlated with the number of thrips found on leaves and fruits.

C. Life Cycle Duration

1. The life cycle of the red-banded thrips on leaves of 'Beaumont' guava was found to be 4.4 ± 0.5 days for the first larval instar, 8.4 ± 1.7 days for the second larval instar; 1.2 ± 0.2 for the prepupa and 2.8 ± 0.5 for the pupa.

D. Leaf Preference Tests in Laboratory

1. The leaf preference test developed in this study worked well as the first step in screening for thrips resistance in clones in the laboratory.
2. The number of fecal spots and/or the number of thrips per leaf disk can be used as an index to rate thrips preference for leaves.
3. Leaves of clones 143, 148, 'Beaumont' and 196 were the most susceptible.
4. Leaves of clones 168, 180, 132, 156 and 157 were the most resistant.

E. Fruit Preference Tests in Laboratory

1. The fruit preference test developed in this study showed very few differences in thrips resistance in clones in the laboratory.

F. Comparison of Laboratory and Field Results

1. Clones 180, 168, 132 and 156 were the most resistant.
2. Clones 143, 148 and 'Beaumont' were the most susceptible.
3. Clones 157, 159, 156 and 196 were intermediate in resistance.

APPENDIX

TABLE 13

DAILY PRECIPITATION mm - WAIMANALO EXPERIMENTAL FARM

	Month	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
			DAY OF MONTH																														
1975	MAR	112.75			.25	1.75	.50		1.25					1.25	1.50			1.50				.50	.25				2.50		10.00	51.50	19.25	19.00	1.75
	APR	32.25	15.75		.50					1.75									1.00	.50	.50	1.75	1.00	1.25	.25	5.00	.50	2.00	.50				
	MAY	19.00						2.75		3.75						.50	1.50							.50		1.00							
	JUN	5.50																							.75		.50		3.00	1.25			
	JUL	20.25	1.75										1.50	1.75					.25	3.00	1.00					4.25	6.75						
	AUG	11.00	2.75			.50				.25	1.25	2.00				1.00	.50							1.25									1.50
	SEP	9.00									1.75								.25		4.25							1.50	.75				
	OCT	23.00		1.00	1.00	.50	1.25	3.75	2.50	4.25				.50							1.75				2.50			.75	.25	.25	2.75		
	NOV	246.25	.25	.75		.75			.50	2.75	3.00	.25	1.00	.50			1.75		.50	5.50	1.00	10.25		3.00		35.50	21.00	74.00	85.50	1.00			
	DEC	23.75			2.00		1.75				3.00		2.50		6.75	4.75	2.00	.25	.25												.25	.25	
1976	JAN	78.25	8.00	.25			.25	2.25			.75				1.25		.75	16.50		1.00			3.50			5.75	.75		.25			3.00	34.00
	FEB	185.50	.75	.50			.50	36.50	68.00	34.00	1.50	.25			4.50	3.00	.50	.75	.25					5.25	.50	.25				28.00			
TOTAL		764.50																															

Source: U.S. Weather Bureau - Climatological Data - Hawaii, April 1975-March 1976

TABLE 14

DAILY TEMPERATURE °C WAIMANALO EXPERIMENTAL FARM

DAY OF MONTH

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1975																																
MAR	MAX	25.0	25.6	25.6	23.9	24.4	23.9	25.6	25.6	25.6	26.1	25.6	25.6	25.6	25.0	25.6	25.0	25.6	25.6	26.1	25.6	25.6	25.6	25.6	25.6	27.8	28.3	27.8	27.2	21.7	23.9	25.0
	MIN	20.0	19.4	18.3	18.3	18.9	18.9	18.9	20.6	20.0	20.0	20.6	20.0	18.9	20.0	20.0	19.4	20.6	21.1	20.6	18.9	20.0	20.0	20.6	18.3	18.3	17.2	18.3	16.7	13.8	15.0	18.9
APR	MAX	25.9	25.0	25.6	25.6	25.6	25.6	25.6	26.1	26.1	26.7	27.2	26.7	28.3	27.8	27.2	26.7	26.1	25.6	25.6	26.1	25.6	25.6	25.6	24.4	23.9	25.0	25.0	25.6	26.1	26.7	
	MIN	18.3	20.6	19.4	20.6	20.6	20.6	21.1	20.0	20.0	17.2	16.7	17.8	18.3	20.0	20.0	20.0	19.4	20.0	20.0	20.0	18.9	18.9	20.0	18.9	20.0	20.0	20.6	21.1	21.1	21.1	
MAY	MAX	26.7	26.7	26.7	26.1	25.6	25.6	26.1	25.0	26.7	26.7	27.2	27.2	27.2	27.2	26.7	27.2	26.7	27.2	27.8	27.2	26.7	26.7	27.8	25.6	26.7	27.8	27.8	27.2	27.8	28.3	28.3
	MIN	21.1	21.1	21.7	21.1	26.1	20.0	21.1	19.4	20.6	18.3	20.0	20.0	20.0	20.6	20.0	21.7	21.1	20.6	21.7	21.7	20.6	21.1	20.0	19.4	20.6	21.1	21.1	20.6	20.0	18.3	21.1
JUN	MAX	27.8	27.8	27.8	28.3	27.8	27.8	27.8	28.3	28.3	27.8	27.8	27.2	27.8	27.2	27.8	27.2	27.8	27.2	28.3	27.8	27.8	27.8	27.8	28.9	27.8	27.8	27.8	27.2	27.2	27.8	
	MIN	21.1	21.1	21.7	21.7	21.7	21.7	21.7	21.7	21.1	21.1	21.1	21.1	22.2	21.7	21.1	20.6	21.7	21.7	20.6	22.2	22.2	20.0	20.6	22.8	21.7	21.1	20.0	21.7	21.7	22.2	
JUL	MAX	27.8	27.8	27.8	28.3	28.3	28.9	28.3	27.8	28.3	28.3	28.3	27.8	27.2	27.8	28.3	28.9	28.3	27.8	28.9	28.9	28.9	28.3	28.9	28.9	26.1	28.3	28.9	28.9	28.3	28.9	29.4
	MIN	20.6	21.7	22.2	22.2	22.2	22.2	22.2	21.7	21.7	20.6	20.0	20.0	21.1	21.7	22.2	22.8	21.1	21.1	21.7	22.2	22.2	22.2	22.8	20.0	20.0	22.2	22.2	22.2	23.3	23.3	22.8
AUG	MAX	27.8	28.3	28.9	27.2	28.9	28.9	28.9	28.9	28.3	26.7	28.3	29.4	28.3	27.8	28.3	28.3	28.3	28.3	28.3	28.9	28.3	28.9	28.9	28.9	28.9	28.9	28.9	28.9	29.4	28.9	28.9
	MIN	22.2	22.2	22.8	21.7	22.8	22.8	22.8	21.7	20.6	21.1	22.2	22.8	23.3	22.2	22.2	22.8	21.7	22.2	23.3	22.8	22.8	22.8	20.7	22.8	22.8	22.2	22.8	22.2	22.8	22.2	21.7
SEP	MAX	29.4	29.4	28.9	28.9	29.4	29.4	28.9	28.9	28.9	28.9	29.4	31.7	30.6	29.4	28.9	28.9	27.2	28.9	28.9	28.9	28.9	29.4	28.3	28.9	28.9	28.3	30.0	28.9	28.9	30.0	
	MIN	21.1	23.3	22.8	23.3	23.3	22.8	21.1	20.0	20.6	23.3	17.8	19.4	21.7	23.3	23.3	22.8	21.7	22.8	22.8	20.6	20.6	20.6	22.8	22.8	22.8	22.8	22.8	22.2	23.3	23.3	
OCT	MAX	29.4	30.0	28.9	28.8	28.9	28.3	28.3	27.2	28.3	28.9	28.3	28.3	27.8	26.7	28.3	28.3	28.3	28.3	28.3	27.8	28.9	29.4	30.0	30.0	28.9	27.8	28.3	28.3	27.8	26.7	27.8
	MIN	22.8	22.2	22.8	22.2	22.2	22.2	22.8	21.7	22.8	22.8	22.2	23.3	23.3	23.3	23.3	22.8	22.2	22.8	22.2	22.8	22.8	19.4	18.3	19.4	20.6	22.2	21.1	22.2	21.1	20.0	17.8
NOV	MAX	28.3	28.3	27.8	27.8	27.8	28.3	27.8	26.7	26.7	27.2	26.7	27.8	27.8	27.8	27.2	27.2	26.7	26.1	26.7	26.7	26.7	27.2	27.2	26.7	25.6	24.4	25.6	25.6	26.7	26.7	
	MIN	19.4	20.6	20.6	21.1	21.1	22.2	22.2	21.7	21.1	21.1	21.7	22.2	22.2	21.1	20.6	22.2	20.6	20.0	21.1	21.1	22.2	20.6	20.0	18.3	19.4	20.6	21.1	20.0	20.0	18.9	
DEC	MAX	26.7	26.7	26.7	26.7	27.2	27.2	26.7	27.2	26.1	25.6	25.6	26.1	23.9	24.4	23.9	25.6	25.6	26.1	25.6			26.1	26.7	26.7	26.7	26.7			27.2	27.2	26.7
	MIN	18.3	21.1	21.1	22.2	21.1	21.2	19.4	18.3	14.4	13.9	15.6	18.9	20.0	21.1	21.1	22.2	21.1	19.4	18.9			16.7	17.2	17.2	16.7	16.7			16.7	21.1	17.8
1976																																
JAN	MAX	27.2	24.4	25.6	25.0	25.6	25.6	27.2	27.2	26.1	25.0	25.0	25.6	25.6	26.1	25.6	26.7	23.9	25.6	26.1	25.0	25.6	25.6	25.6	27.8	26.7	27.8	28.9	26.7	25.6	27.8	24.4
	MIN	17.8	21.7	21.1	21.7	18.9	21.7	22.2	20.6	20.0	20.0	20.6	20.0	20.6	21.1	17.2	17.2	18.9	17.2	16.1	17.2	16.7	18.3	17.2	18.3	17.2	20.0	18.3	18.3	17.8	17.8	18.3
FEB	MAX	22.2	23.9	22.8	25.6	24.4	23.9	23.3	23.9	21.1	25.0	25.0	26.1	25.6	25.0	25.6	25.0	23.9	25.0	25.6	25.6	26.1	25.6	24.4	25.6	24.4	25.6	26.1	26.1	25.6		
	MIN	15.8	13.3	13.3	15.0	18.3	17.8	17.8	17.8	16.7	17.2	17.8	20.0	19.4	20.0	20.0	20.0	20.6	20.6	20.6	20.6	21.1	19.4	20.0	20.6	20.6	17.8	16.7	16.7	17.2		

Source: U.S. Weather Bureau Climatological Data - Hawaii, April 1975-March 1976

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